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Economic Impact of Change in pH Regulation, R76-21

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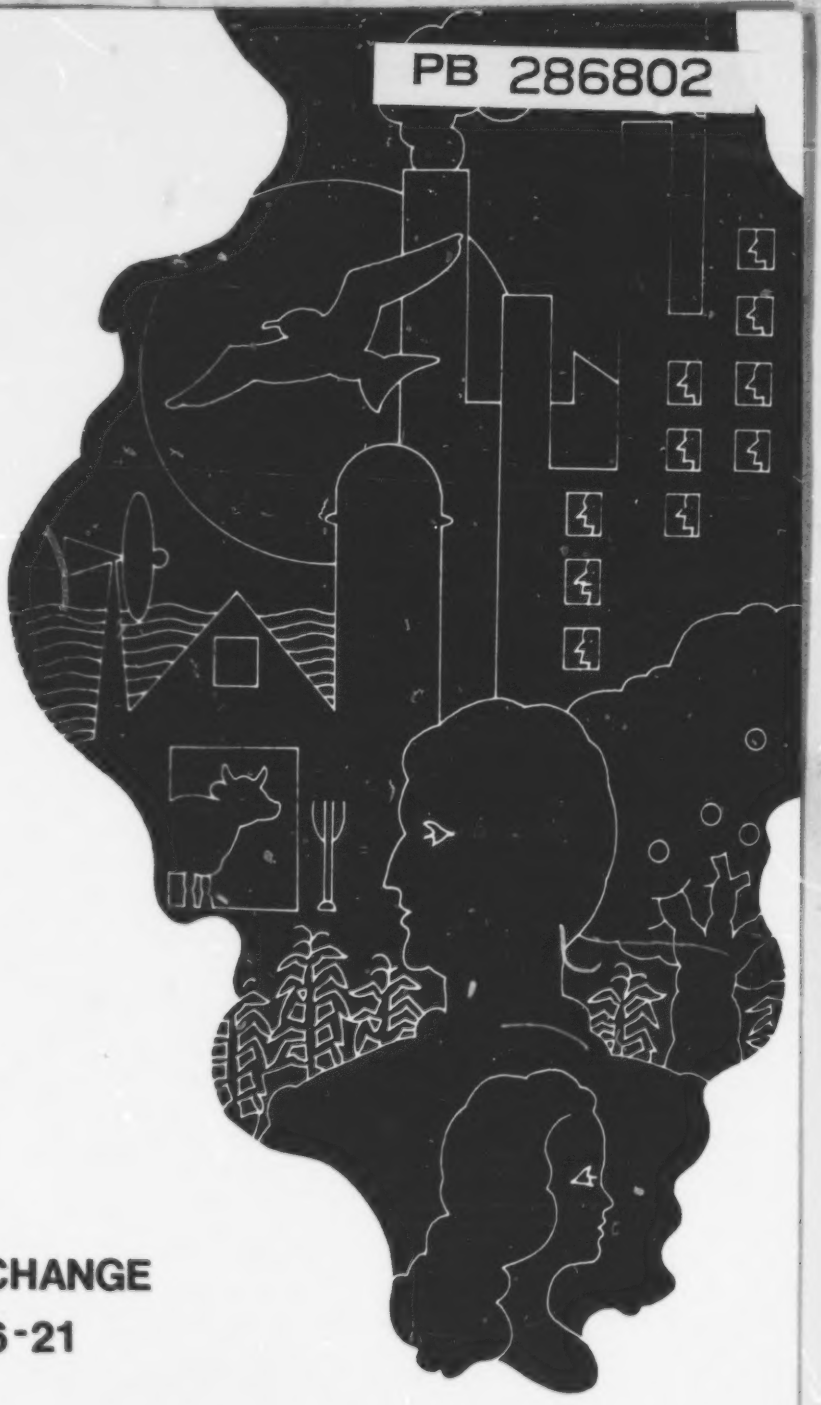

ECONOMIC IMPACT OF CHANGE IN pH REGULATION, R76-21

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CHANGE IN pH REGULATION, R76-21

by

Linda L. Huff
John Raevuori

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State of Illinois
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May, 1978

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Opinion of the Economic Technical Advisory Committee
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The Economic Technical Advisory Committee has reviewed the economic impact study IIEQ Document No. 78/01, entitled, Economic Impact of Change in pH Regulation, R76-21. The Committee finds the report to be generally responsive to the requirements of Section 6 of the Environmental Protection Act and recommends that it be forwarded to the Pollution Control Board so that the public economic impact hearings may be held in connection with proposed regulation R76-21, EFFLUENT STANDARDS REVISIONS, which seeks to amend rule 408 of Chapter 4, Water Pollution Regulations.

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EXECUTIVE SUMMARY

Regulatory proposal R76-21, which is being considered by the Illinois Pollution Control Board, includes a revision of the present effluent pH standard of 5.0 to 10.0 units to a more restrictive limitation of 6.0 to 9.0 units, to be met at all times without averaging. This change would achieve uniformity with U.S. EPA effluent guidelines for which the economics and technology have been well established.[10]

The Illinois Environmental Protection Agency has proposed an amendment to the proposed pH limitation which would allow excursions beyond the 6.0 to 9.0 range if the excursion were due entirely to natural causes. This amendment would, in effect, allow dischargers with lagoon operations to exceed the 6.0 to 9.0 pH limits during warm weather months. Such excursions typically occur between the months of April and October, when conditions are optimal for biological growth.

The consequence of regulatory change, R76-21, would be to attain pH levels in streams closer to a neutral pH of 7.0. However, the magnitude of the predicted change in water quality is so small that benefits to water users are considered not measurable. Existing water quality pH violations and trends monitored by the IEPA are attributed to non-point sources of pollution, and thus enactment of the proposed revision is not expected to impact these violations. Increased protection for biota in small and intermittent streams which receive lagoon dischargers is expected from the proposed regulation. These lagoons dischargers typically have high ammonia concentrations and high pH values in their effluents during warm months. Such a combination of conditions increases

the amount of unionized ammonia and thus the toxic effect on fish in small and intermittent streams. If the IEPA amendment is adopted, the degree of protection afforded 82 ammonia water quality limited streams receiving lagoon discharges will not be subject to improvement over present water quality.

Costs of the proposed revision will be incurred by municipal, private, and industrial dischargers for additional pH control facilities. Unit capital investment and operating costs for increased pH treatment varied depending upon the discharger type. Total capital expenditures predicted to result from the proposed revision without the IEPA amendment are between $3.5 million and $5.3 million. If the IEPA amendment is enacted, total capital costs of the revision would be reduced to a range of $0.37 million to $0.49 million. This would entail a cost savings of $2.9 million to $4.6 million. In addition to these capital costs, there are those which have already been incurred by dischargers to meet the present U.S. EPA limit of 6.0 to 9.0 pH units, and this value is estimated to be between $0.33 and $0.36 million.

Operating costs would also be incurred by these impacted facilities, and if the R76-21 proposal is adopted, the annual operating cost would be between $0.55 to $0.76 million. If the IEPA amendment is also adopted, these annual operating costs are reduced to $0.25 to $0.29 million.

With acceptance of the IEPA amendment, 164 lagoon operations will be exempted from pH control costs, and only six industries will be required to install treatment facilities while 19 others need to improve

operation of their treatment system. No economic impact upon agriculture, local government, commerce or industry would thus be anticipated if the proposed pH regulation R76-21 and the IEPA amendment are adopted. However, if there is no exemption for lagoon dischargers during summer months, then the following groups will incur additional costs:

Discharger Type	Number of Facilities Affected
Nursing homes	3
Mobile home parks	14
Schools	8
Miscellaneous	11
Industry	3
Municipalities	125

The primary cost burden is imposed upon small municipalities of population typically less than 2500 and mobile home parks. The increased operating expense and capital cost of pH control would result in increased taxes to citizens in these communities if services are maintained at their current level. Thus, 164 local governments or private dischargers, combined, may incur increased operating costs of $300,000 to $450,000 per year to obtain pH control if the IEPA amendment is not adopted. No impact upon agriculture, industry, or commerce should occur as a result of the IEPA amendment.

Chapter 1

INTRODUCTION

In February, 1977, the Illinois Institute for Environmental Quality (IIEQ) proposed that the Pollution Control Board adopt specific modifications to Chapter 3, Part IV, Rule 408 of the Water Pollution Regulations. These changes included a revision of the present pH effluent limitation from 5 to 10 units to a more restrictive limitation of 6 to 9 to be met at all times (without averaging in both cases).* The Illinois Environmental Protection Agency (IEPA) on May 2, 1977 amended this proposal to permit excursion beyond the pH effluent limits of 6.0 to 9.0 if the excursion were attributable entirely to natural causes. Both the IIEQ proposal and IEPA amendment are the subjects of this analysis of economic and environmental consequences.

The motivation for the IIEQ proposal is to achieve uniformity with U.S. EPA effluent standards which have been considered technologically and economically well established.[10] In all U.S. EPA effluent guidelines promulgated for industry, a pH range of 6.0 to 9.0 units has been stipulated and enforced. The IIEQ proposed modification would result in consistent state and federal limitations. The IEPA amended the proposed regulation because the treatment method utilized by many small municipal and private dischargers results in high pH values in the effluent. Towns of less than 2500 citizens and small private facilities typically have lagoon systems and/or polishing lagoons. Algal activity during the summer results in pH values above 9.0 units, and the IEPA believes such excursions should be exempted from the pH limitation.

*pH standard is not subject to averaging. The range will be met at all times (see Appendix A).

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By restricting the range of effluent pH values that are acceptable, an improvement in water quality beneficial to aquatic life and water users may occur. Reducing the fluctuation in effluent quality would impact the biota and users immediately downstream, even though the pH water quality limits of 6.5 to 9.0 units are not violated. Swimming activities are more desirable when waters have a pH range of 6.3 to 8.5 units because of reduced eye irritation.[15] Thus, users for water contact sports may benefit from the proposed regulation. Costs to industries and municipalities for treatment of surface water prior to use may increase or decrease, depending upon the treatment technology utilized, and therefore such water using groups will be investigated. Perhaps the most important result of a change in the effluent pH limitation would be the synergistic effluents of effluent pH with other stream pollutants upon the stream biota. Such a concern is discussed in Chapter 3.

The direct results of enacting R76-21 specific to the pH modification is an increase in treatment costs for certain municipal and industrial dischargers. Since the Federal EPA is presently enforcing a pH standard of 6.0 to 9.0, and not permitting averaging, industrial dischargers have already paid the costs of additional pH control. One hundred twenty-five municipal and 39 small private dischargers, such as mobile home parks and schools, would be required to install pH control during summer months, unless the IEPA amendment is adopted. These small facilities are a primary concern in this study and will be discussed in detail.

Three scenarios are evaluated within this study. Scenario A is the existing regulatory situation, of pH 5 to 10, which is used as a basis for comparing Scenario B and C. Scenario B illustrates the impact of the proposed standard with the exemption for excursions due to natural causes while the impact without the excemption represents Scenario C.

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Chapter 2

CURRENT AND ANTICIPATED ENVIRONMENTAL CONSEQUENCES

The proposed regulation restricts the range of pH values allowed in effluents and thus an improvement in water quality may be anticipated. However, this proposed change does not measurably improve the water quality in Illinois because few areas indicate that a problem with pH exists, and because the effects of effluent pH are rapidly diminished through neutralization by the natural buffering system of surface waters. IEPA water quality data reveal that only two streams consistently violate the general use water quality standard of pH 6.5 to 9.0, and both of these violations occur in streams which receive runoff from mining activities. However, water quality may be affected in small intermittent streams which are not routinely monitored by the IEPA. Thus, not all potential impact of the rule change is readily identified. The existing pH water quality patterns in Illinois and anticipated changes are described herein to delineate the magnitude of expected environmental consequences associated with the proposed regulation.

2.1 Water Quality Chemistry

The pH of natural waters is a measure of the acidic activity of that water and is influenced by both the mineral content and algal activity. When wastewaters with pH levels different from those of the receiving stream combine with the natural water, a variety of impacts may result, depending upon the acidity, alkalinity, and the

buffering capacity of the mixture. A description of these three factors follows in order that the water quality impact may be better understood.

The buffering capacity of water is its ability to resist changes in pH. It is due primarily to the presence of the salts of weak acids, although weak or strong bases may also contribute. The principal buffering system in natural waters is the bicarbonate-carbonate system. This system is the result of the combination of carbon dioxide with water, which forms a weak carbonic acid and dissociates into bicarbonate and carbonate ions according to equation 1.[13]

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^- \rightleftarrows 2H^+ + CO_3^= \qquad (1)$$

The bicarbonate (HCO_3^-) and carbonate ($CO_3^=$) ions represent the buffering action of the water. The carbon dioxide that is necessary for this system is readily available from the atmosphere and from biological respiration.

The capacity of a water to neutralize bases is termed acidity.[13] Acidity is a gross measurement and is principally caused by dissolved carbon dioxide and minerals. It is analytically measured by titrating with a strong base to an end point of pH 8.5, and is expressed as mg/ℓ calcium carbonate. Although waters with high amounts of acidity may have a low pH, the relationship between pH and acidity is not linear. Acidity measures the combined effect of several chemicals, while pH indicates the activity of the hydrogen ions in solution.

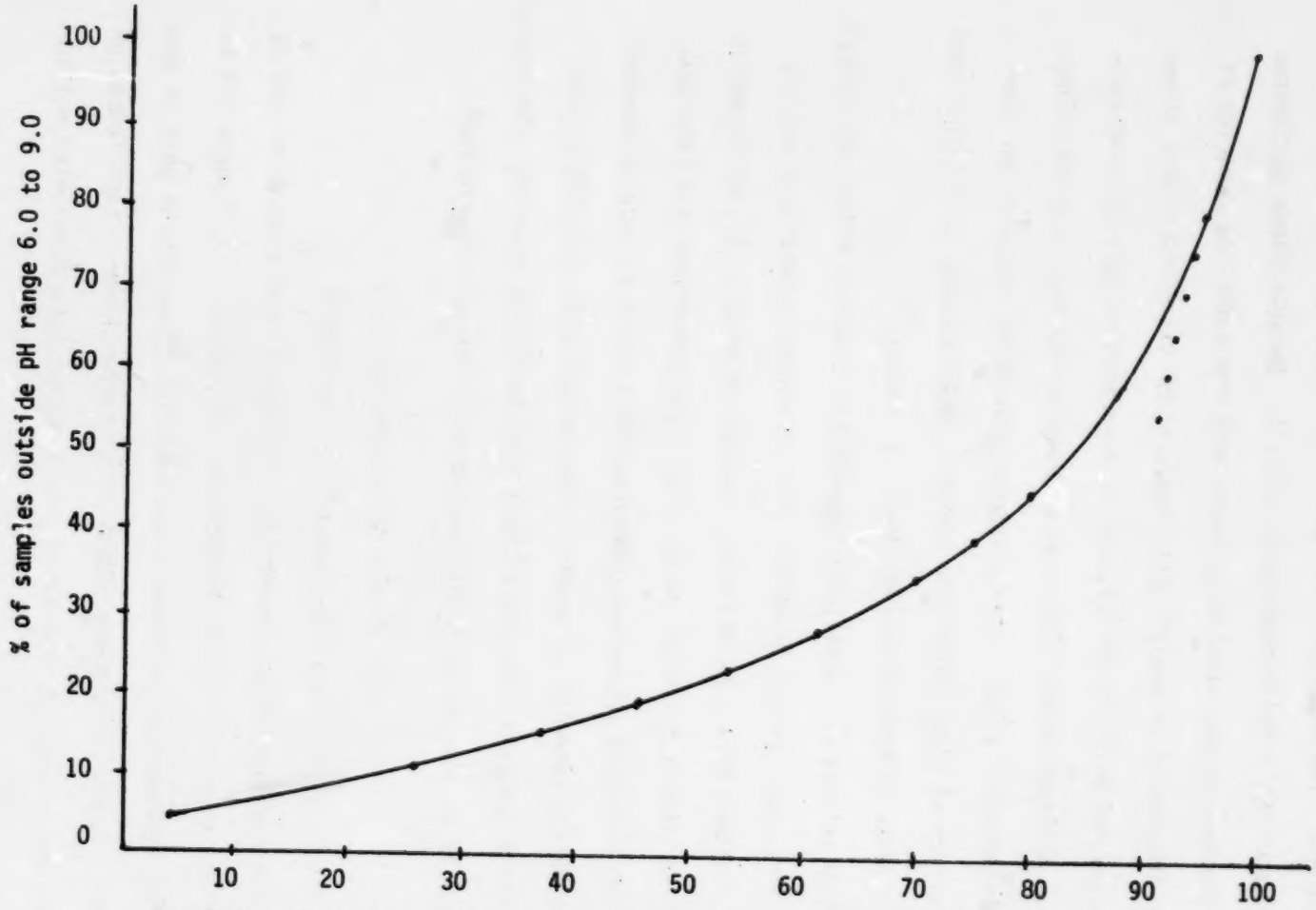
Another important characteristic of water is its capacity to neutralize acids, called its alkalinity.[13] Alkalinity is a gross measurement of the combined amount of weak acids, weak bases, and

strong bases. The major portion consists of hydroxyl ions (OH^-), carbonate ions ($CO_3^=$) and bicarbonates (HCO_3^-). Because these substances resist changes in pH, alkalinity represents the buffering capacity of water. Alkalinity is analytically measured by titrating with a strong acid to an end point of pH 4.5, and is expressed as mg/ℓ calcium carbonate. Although waters with high alkalinity may have high pH values, the relationship is not linear, because alkalinity measures the combined effect of basic chemicals present. Most streams in Illinois have an alkalinity between 50 and 200 mg/ℓ (as $CaCO_3$).[8]

Both acidity and alkalinity measure the combined effect of several substances, and coexist in waters with pH values between 4.5 and 8.5 units. Waters with a pH below 4.5 contain no alkalinity, while waters with a pH above 8.5 contain no acidity. Both properties are important in water treatment processes, but alkalinity alone is used to measure the buffering capacity of water. Thus, waters with relatively high alkalinity contents, and therefore a high buffering capacity, can resist changes in pH more effectively than waters with low alkalinities.

2.2 Discharger Characteristics

Review of the IEPA monitoring data indicated that 331 municipalities, commercial facilities, and industries had at least one violation of the proposed pH limitation. In Figures 2-1 and 2-2 the frequency of effluent violations for these dischargers is presented. Approximately one-fourth of these dischargers experienced pH excursions between 0% and 10% of the time and were considered not to



Cumulative Percentage of Impacted Dischargers with Effluent Violations Less than the Percentage Shown on Y-Axis

Figure 2-1

FREQUENCY DISTRIBUTION OF EXCURSIONS FROM pH RANGE 6.0-9.0

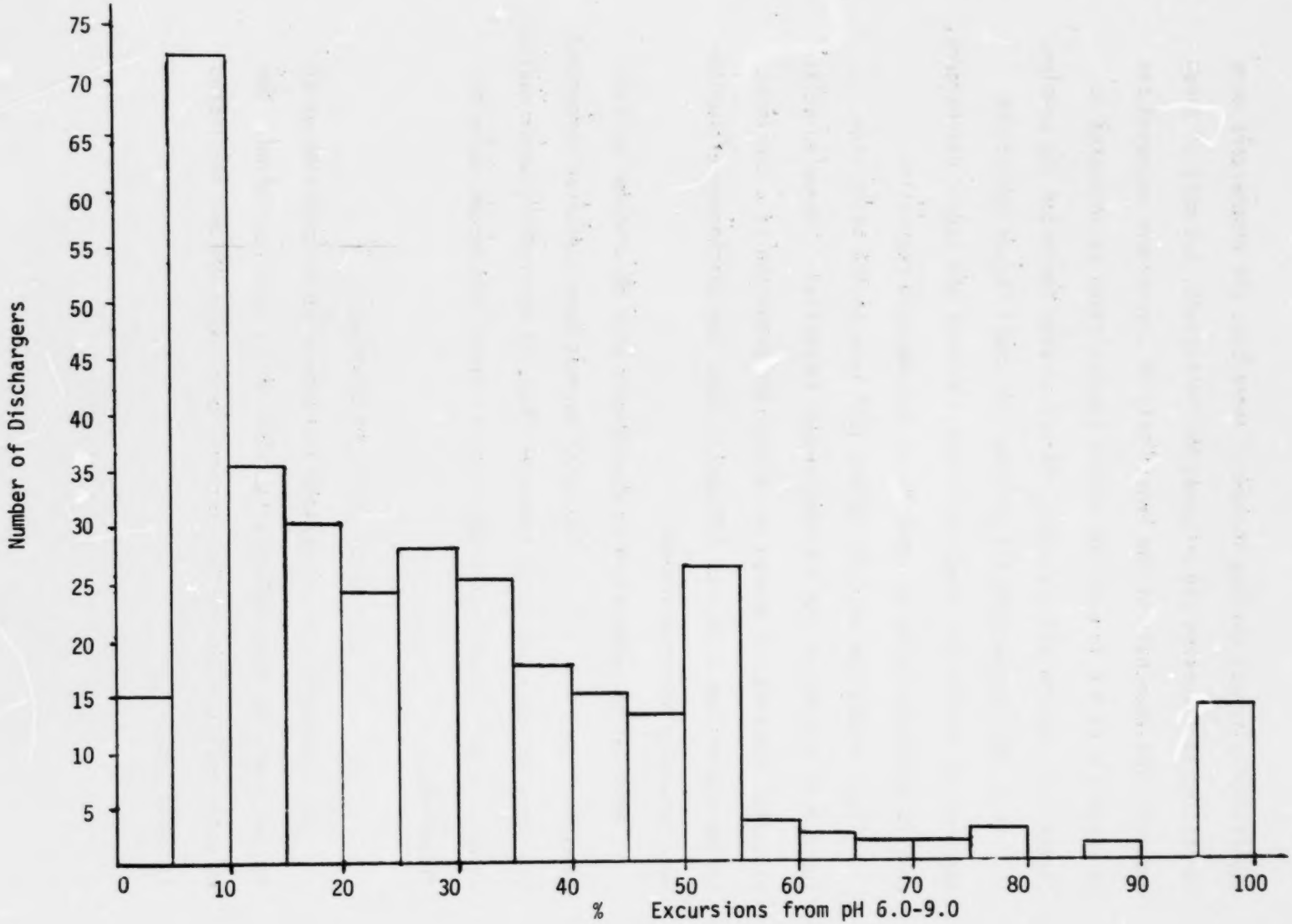


Figure 2-2

FREQUENCY DISTRIBUTION OF DISCHARGERS EXCEEDING THE pH RANGE OF 6.0 - 9.0

significantly impact the environment. Therefore, 244 dischargers were identified as exceeding the proposed pH limitations, and most of these occurred less than half of the time. Only 56 dischargers exceeded the pH range 6.0 to 9.0 in over 50% of the samples taken as indicated in Figure 2-2. Of the 244 violators, 55 had already corrected the problem.

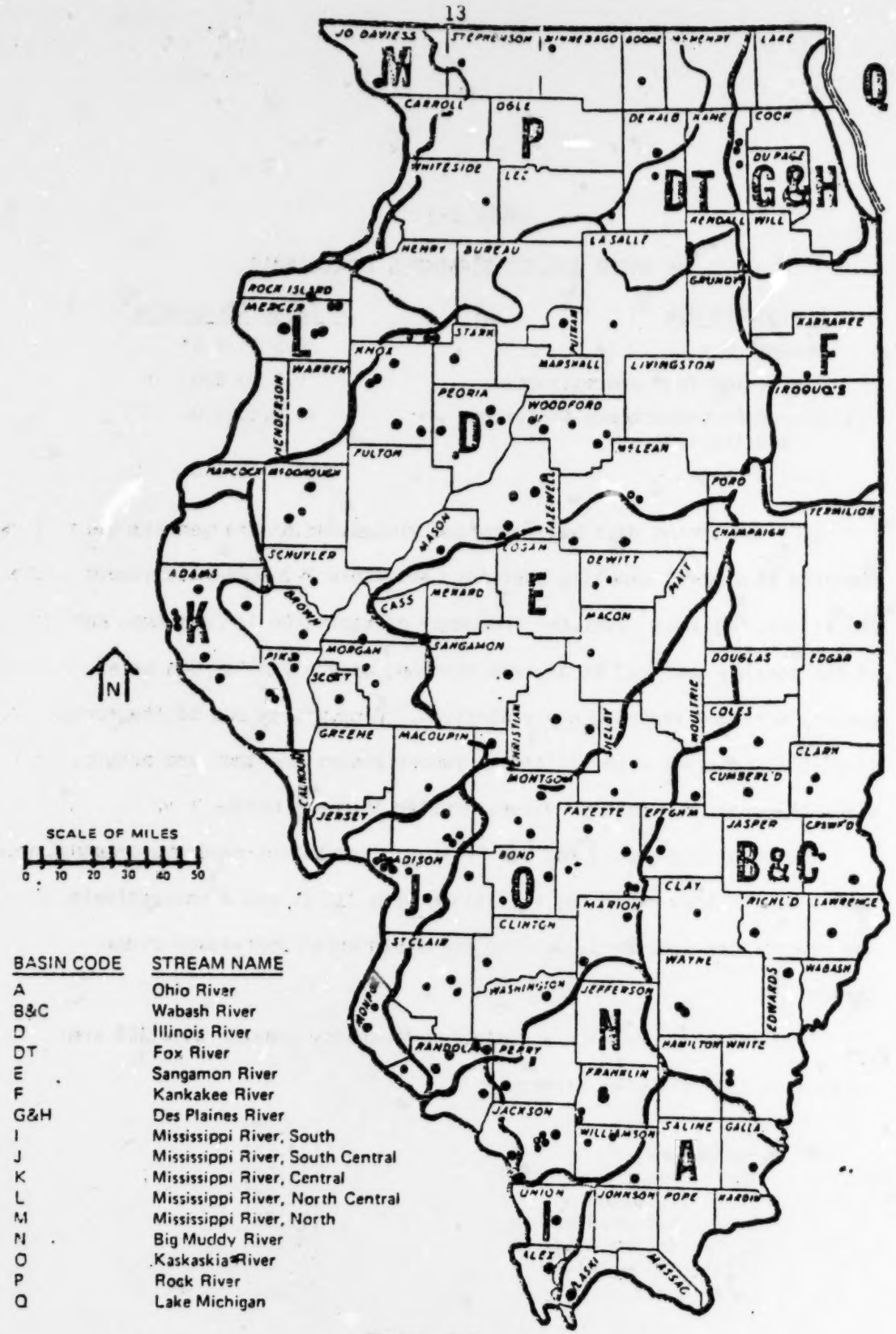
Thus, 189 dischargers, 164 of whom are small lagoon operations appeared to violate the proposed limits. Without the lagoon dischargers, only 25 violators could be impacted by the proposed regulation.

These violations recorded by the IEPA were on the basic side (pH > 9.0) for 240 of the 244 dischargers identified. Where an acidic excursion occurred, it seemed to reflect the breakdown of a treatment system rather than a typical effluent. Thus, the discharger effluents were generally basic violations.

There was no aggregation of dischargers with pH problems as indicated by Figure 2-3. The point sources were scattered throughout the state on small and large streams. Thus, in determining water quality effects, no particular trends due to point source discharges could be discerned.

2.3 Water Quality Violations

The quality of Illinois waters was determined by comparing existing pH levels to those values stipulated in Illinois regulation. The pH water quality standards vary according to water use and are listed in Table 2-1.



BASIN CODE	STREAM NAME
A	Ohio River
B&C	Wabash River
D	Illinois River
DT	Fox River
E	Sangamon River
F	Kankakee River
G&H	Des Plaines River
I	Mississippi River, South
J	Mississippi River, South Central
K	Mississippi River, Central
L	Mississippi River, North Central
M	Mississippi River, North
N	Big Muddy River
O	Kaskaskia River
P	Rock River
Q	Lake Michigan

Figure 2-3

LOCATION OF DISCHARGERS IMPACTED BY pH REGULATION

Table 2-1

pH WATER QUALITY STANDARDS IN ILLINOIS

Designated Use	pH Range Acceptable
General Use	6.5 to 9.0
Public and food processings	6.5 to 9.0
Secondary contact and indigenous aquatic life	6.0 to 9.0
Lake Michigan	7.0 to 9.0

IEPA monitoring data have recorded violations of the general use standard at several sampling stations, and Table 2-2 summarizes these violations. In most cases the frequency of violation is less than 10% of the samples analyzed at a given station, and only 45 of 576 water quality stations reported any violations. Also, forty out of the forty-five (87%) stations with violations report excursions that are acidic, while the remainder have pH values greater than 9.0 units.

The Ohio, Big Muddy, and Des Plaines River basins have the greatest number of stations reporting violations with 11, 8, and 8 respectively. The other water quality excursions are distributed over seven river basins.

Sampling stations with a violation frequency greater than 10% are located on the following streams:

Mary's River	(12.5%)
Pond Creek	(12.5%)
Thorn Creek	(12.5%)
State St. Ditch	(11.8%)
S. Fk. Saline River	(83.9%)
S. Fk. Saline River	(96.8%)
Little Saline River	(21.7%)
Sugar Creek	(100%)

Table 2-2

WATER QUALITY STATION VIOLATIONS IN ILLINOIS

Basin	Number of Water Quality Stations with the Following Violations: 1-10% Acidic	1-10% Basic	11-20% Acidic	11-20% Basic	21-30% Acidic	21-30% Basic	31-80% Acidic	31-80% Basic	81-90% Acidic	81-90% Basic	91-100% Acidic	91-100% Basic
Ohio River	11	-	-	-	1	-	-	-	1	-	2	-
Wabash	4	-	-	-	-	-	-	-	-	-	-	-
Illinois	-	2	-	-	-	-	-	-	-	-	-	-
Fox	1	1	-	-	-	-	-	-	-	-	-	-
Sangamon	-	1	-	-	-	-	-	-	-	-	-	-
Des Plaines	3	3	2	-	-	-	-	-	-	-	-	-
Miss. South	-	-	1	-	-	-	-	-	-	-	-	-
Miss. South Cent.	-	2	-	-	-	-	-	-	-	-	-	-
Miss. Central	1	-	-	-	-	-	-	-	-	-	-	-
Big Muddy	8	-	1	-	-	-	-	-	-	-	-	-
Total number of water quality stations	28	9	4	0	1	0	0	0	1	0	2	0

A - acidic violation, pH < 6.5

B - basic violation, pH > 9.0

Source: IEPA Water Quality Data, 1976-1977.

All of these stations reported pH violations on the acidic (pH < 6.0) side. The South Fork of the Saline River, the Little Saline River, Sugar Creek, Mary's River and Pond Creek are located in the Saline River and Big Muddy River Basins, which receive runoff from mining activities. No acidic effluent pH violations attributed to municipal or industrial discharges have been recorded on these five streams as indicated by Figure 2-3. Chapter 4 of the Illinois Water Pollution Regulations stipulates separate effluent requirements for mining activities. Therefore, water quality violations attributed to these discharges are not affected by the proposed Chapter 3 regulation; however, water quality standards are applicable to all streams in these coal mining areas. Thorn Creek and State Street Ditch are both located in northeastern Illinois, where ambient pH levels are usually above 7, as discussed in Section 2.4. However, there is no correlation between the location of effluent violations recorded by the IEPA and these water quality violations.

The IEPA has reported that the pH of the Big Muddy River remained within the range 7 to 8 in 1972, 1973, and 1974.[14] This indicates that the acidic condition of its tributaries has not affected the main stem of that drainage basin. The same water quality condition exists for the Saline River as well.

The pH water quality of Illinois streams appears to be generally within the specified use standards as evidenced by 531 of 576 stations. A possible factor affecting pH levels in streams is geological compositions and the next section describes in detail the geological factors

affecting pH levels in Illinois streams.

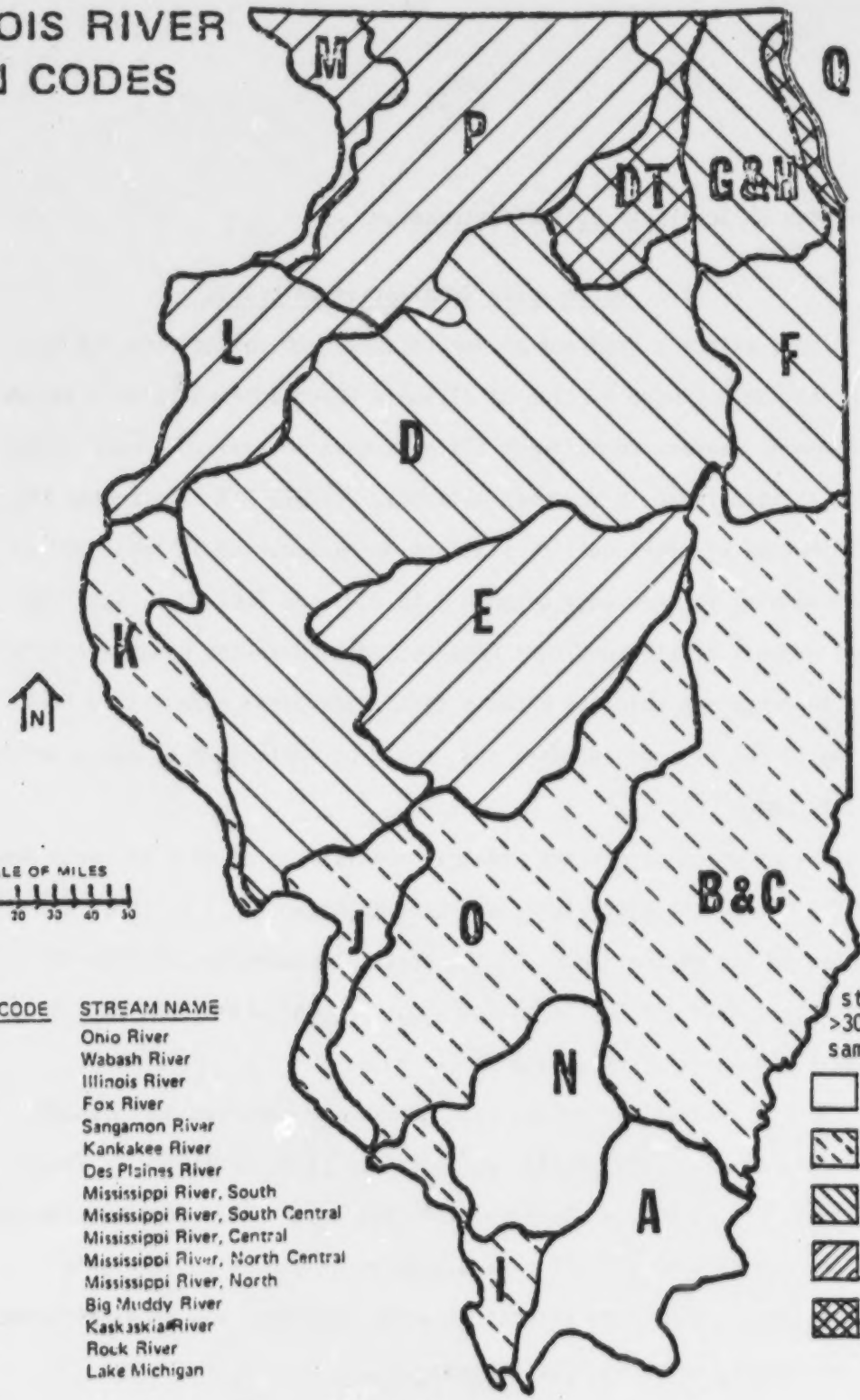
2.4 North-South Gradient of pH Levels

There exists a gradient of natural water pH values from the northern to the southern portion of Illinois which appears to be a natural phenomenon. Waters in northern Illinois have on average a much higher pH level than those in southern Illinois. Figure 2-4 illustrates the distribution of water quality stations which reported at least 30% of their samples in the range of pH 8.4 to 9.0, and Table 2-3 lists the total numbers of stations that have recorded pH in the range 8.4 to 9.0. This pH range was selected because it is considered potentially irritating to the eyes of swimmers and would be indicative of any water quality trend.

Basins which report the greatest consistency of this pH range are the Fox River, the Rock River, and Lake Michigan. All of these are located in the northern part of the state. Occurrences of high pH become less frequent in the southern part of the state, and thus a north-south pH gradient exists in Illinois.

The pH gradient coincides with previously reported north-south gradients of mineral variability,[8] hardness[8] and alkalinity.[6] These gradients are attributed to high sustained groundwater contribution and surface runoff from soil of recent glacial origin which is highly mineralized.[8] Thus, the effects of these gradients may be significant in determining water quality impacts.

ILLINOIS RIVER BASIN CODES



BASIN CODE	STREAM NAME
A	Ohio River
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G&H	Des Plaines River
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J	Mississippi River, South Central
K	Mississippi River, Central
L	Mississippi River, North Central
M	Mississippi River, North
N	Big Muddy River
O	Kaskaskia River
P	Rock River
Q	Lake Michigan

Figure 2- 4

WATER QUALITY TRENDS IN pH LEVELS

Table 2-3

WATER QUALITY STATIONS WITH pH VALUES 8.4 to 9.0

River Basin	No. Stations with Samples pH 8.4-9.0	No. Stations with > 30% of samples at pH 8.4-9.0	Total Number of stations	% Stations with >30% of samples at pH 8.4-9.0
Ohio	8	0	33	0
Wabash	35	6	55	11
Illinois	61	29	62	47
Fox	46	46	46	100
DU.-D22P	5	4	5	80
Sangamon	31	18	33	54
Kankakee	8	4	9	44
Des Plaines	131	51	135	38
Mississippi R., South	1	1	9	11
Mississippi R., South Central	16	3	22	14
Mississippi R., Central	8	2	8	25
Mississippi R., North Central	11	7	11	64
Mississippi R., North	12	9	12	75
Big Muddy River	3	0	27	0
Kaskaskia River	18	7	30	23
Rock River	45	45	45	100
Lake Michigan	33	33	34	97

2.5 Environmental Consequences of R76-21

The environmental consequences of adopting R76-21 are expected to be negligible as measured by changes in pH water quality levels. The following five factors lead to such a conclusion based upon the data presented in Chapter 2:

1. pH is a non-conservative variable, the effects of which are limited to the point of discharge and a limited distance downstream from the discharge.

2. pH water quality violations have been recorded at 45 out of 576 IEPA monitoring stations, or 8% of the total. Of those 45 stations with recorded violations, 37 show violations in 10% or fewer samples. Of the 8 stations with greater than 10% of the samples in violation, 6 are attributable to acid mine drainage, a non point source of pollution not regulated by R76-21. The two remaining stations cannot be shown to be in violation because of point source discharges.

3. Dischargers with effluent pH violations are distributed randomly throughout the state with no relationship evident between their location and water quality pH patterns. Eighty percent of all stations with water quality violations indicate acidic violations, while 99% of the recorded effluent violations are basic.

4. The pH of natural waters in Illinois appears to be influenced by natural distribution patterns of mineral and soil variability. pH levels of 8.4 and above are common in the northern part of the state, and seldom occur in the south. These patterns are not influenced by the location of dischargers exceeding the effluent pH limitation.

5. Only 25 dischargers other than 164 lagoon operations appear to violate the effluent standard. Such a small number of dischargers would not substantially impact water quality.

If the IEPA amendment is adopted, no change in the number of pH water quality violations is anticipated; however, other effects, such as synergism with other pollutants is a factor. Potential impacts upon streams where lagoon dischargers are located is discussed in detail in Chapter 3.

Chapter 3

BENEFITS

3.1 Introduction

If the proposed pH effluent limitation is adopted, an improvement in water quality is anticipated. Thus, the benefits associated with the rule change relate primarily to environmental gains. Changes in the pH of natural waters could potentially affect eleven uses of water, and the following list represents all of the possible sectors considered in assessing benefits:

Aesthetics
Agriculture
Commercial fishing
Domestic water use
Human health
Industrial water supply
Municipal water supply
Navigation
Power generation
Recreation (water contact)
Recreation (water non-contact)

Of the eleven uses, seven are directly affected and considered in this chapter. These seven uses are agriculture, commercial fishing, human health, industrial water supply, municipal water supply, water non-contact recreation, and water contact recreation. The effects of pH on the remaining four uses (aesthetics, domestic water use, navigation, and power generation) are not impacted and therefore are not discussed in this study.

The pH range desirable for each of the seven water uses is first presented and this is followed by a discussion of the expected environmental benefits. A summary of the net environmental benefits with and

without the IEPA amendment provides a complete description of the alternatives available.

3.2 Desirable pH Conditions for Impacted Uses

The desirable pH ranges for the water uses of agriculture, commercial fishing, municipal water supply, industrial water supply, contact recreation, and non-contact recreation are each described in the following paragraphs.

3.2.1 Agriculture

Agricultural water quality of pH 6.5 to 9.0 is considered safe for crop and drinking water use for livestock based on Chapter 3, Water Pollution Regulations. Federal guidelines list a pH range of 5.5 to 8.5 as desirable for agricultural production, and a range of pH 4.5 to 9.0 as acceptable.[15] Soil is a buffered system, so the soil moisture pH is not significantly affected by application of irrigation water. If the soil were sandy and low in organic matter, Water Quality Criteria suggests that there could be adverse effects.[15] Soils in southern Illinois contain less than 1% organic matter, while soils in central and northern Illinois have greater than 1% organic matter. Waters with pH values below 4.8, such as those impacted by acid mine drainage, may be detrimental to plant growth, but because these waters often contain quantities of heavy metals or other elements toxic to plant growth, the detrimental effects are not attributable to pH alone. Table 3-1 lists the acreage in Illinois according to drainage basin which could potentially be affected by a change in the effluent pH regulation.

Table 3-1

IRRIGATION ACREAGE IN ILLINOIS

Major Drainage Area	Irrigation, 1000 acres
Ohio River	7.0
Wabash River	7.0
Little Wabash River	7.0
Direct Little Wabash Tribs	7.0
Upper Mississippi River	3.3
Big Muddy River	1.5
Illinois River	1.5
Kankakee River	1.0
Des Plaines River	1.0
Fox River	0.5
Direct Miss. Tributaries	0.3
Rock River	0.1
Direct Rock River Tribs.	0.1

pp. III-64

Source: IEPA Water Quality Management Basin Plan Phase I

3.2.2 Commercial Fishing

Commercial fishing occurs in major rivers, such as the Illinois, Ohio, and Mississippi Rivers, for which the general use water quality standard of pH 6.5 to 9.0 is applicable. The pH water quality in these rivers has been within this range and and is adequate protection for commercial species of fish.

3.2.3 Human Health

Although the pH of water used for public consumption is controlled by public water treatment plants, the state requires the pH of the raw water to be between 6.5 and 9.0. The processes of water softening and coagulation, both common practices, are pH dependent, and even result in pH levels in excess of 9.0 units. Readjustment of the pH may be required to prevent corrosive and scale-forming reactions in distribution pipes.[2] As a result, the pH of treated water varies from the pH of raw water. Any benefits associated with public water supplies would be related to the operating costs of water treatment plants, and not to human health.

3.2.4 Municipal Water Supply

Surface waters withdrawn for public use are generally treated prior to use, and the Water Pollution Regulations stipulate an acceptable pH range of 6.5 to 9.0 in raw intake waters. A change in the water quality can result in more costly or less costly water treatment, depending upon the pH level and treatment method. For lime softening higher pH values are desirable,[1] for ion exchange there is no difference,[1] and for

coagulation a limited pH range near 7.0 is beneficial.[1] Thus, for any incremental adjustment within the pH range of 6.5 to 9.0 there may be an increase or decrease in water treatment costs depending upon the techniques utilized.

3.2.5 Industrial Water Supply

Industries draw approximately 1250 million gallons per day (mgd) from surface waters in Illinois to meet their needs.[5] The desired quality of this water with respect to pH level varies for each industry and use. Table 3-2 depicts a range of acceptable values, which, in most instances, exceed the water quality standard.

3.2.6 Recreation-Water Contact

Streams designated as general use may be utilized for water contact recreation, such as swimming. Waters with a pH range of 6.5 to 9.0 are acceptable according to Chapter 3 of Water Pollution Regulations. Federal Water Quality Criteria guidelines specify a pH range of 5.0 to 9.0 as acceptable and a pH range of 6.5 to 8.3 as desirable to avoid irritation of the eyes during swimming.[15]

3.2.7 Recreation-Non Contact

Activities such as fishing rely on the protection of aquatic biota by general water quality standards to produce a satisfactory environment. The general use standard allows a pH range of 6.5 to 9.0 units, and this is considered sufficient protection for aquatic biota.

Table 3-2

RANGE OF pH VALUES IN WATER USED FOR INDUSTRIAL PURPOSES

Water Use	Acceptable pH Range
Cooling water, once through	5.0-8.9
Cooling water, makeup recycle	3.5-9.1
Textile industry, SIC-22	6.0-8.0
Lumber industry, SIC-26	5.0-9.0
Pulp and paper ind., SIC-26	4.6-9.4
Chemical industry, SIC-28	5.5-9.0
Petroleum industry, SIC-24	6.0-9.0
Primary metals industry, SIC-33	3.0-9.0

Source: Clark, Viessman, and Hammer, p. 234.

3.3 Benefits of Regulation

3.3.1 General Benefits to Water Users

In Chapter 2 the general environmental consequences (or benefits) of adopting R76-21 were determined to be insignificant, or, in other words, no change in pH water quality would occur. This is expected because of the relatively satisfactory water quality currently existing in the state and because the impact of non-point sources upon stream pH levels appears to be greater than that of point sources. Improvement in water quality, if not of analytically measurable, makes it difficult to quantify any benefits for water users in the state.

The following valuation for each use area is based upon the conclusion that there will be no measurable change in water quality. The proposed regulation for effluent pH values would have no effect upon commercial fishing activity. For such uses as agriculture, human

health, public water supplies, industrial water supplies, and swimming the benefits of greater protection are so small as to be not measurable. Some incremental change in stream pH may occur near individual dischargers; however, this will have minimal effect on the above listed water usages. The major benefit to be gained from R76-21 is additional protection of localized water quality on small streams. In the following section a detailed discussion of this impact is presented.

3.3.2 Water Recreation-Non-Contact Benefits

One of the most important considerations of this study relates to the effects of pH upon aquatic life in small streams and tributaries. The pH water quality standard of Chapter 3 of the Water Pollution Regulations was established at 6.5 to 9.0 units to protect the aquatic biota. While the vast majority of IEPA's monitoring stations (outside the coal mining regions) comply with the pH limitations, there is concern over the small, intermittent streams. Changes in the localized pH on these small streams can have a drastic effect on the toxicity of the ammonia present in the stream.

Studies dealing with the toxic effects of pH on aquatic life have been limited to acidic conditions. Mount[7] has shown that fish exposed to pH levels below 6.0 show signs of chronic stress in behavioral patterns, growth rates, and reproductive ability. Other reports concerning the effects of low pH upon fish have not been able to isolate pH from the conditions that usually accompany it, such as changes in free carbon dioxide concentration, alkalinity, and the solubility and form of metals.[7] Food supply and nutrient availability also may be low

under extreme pH conditions. For these reasons, literature concerning the toxicity of pH alone is limited.[7]

A primary concern is the effect of pH on the ammonia toxicity in small municipal or private effluents. Ammonia in water exists in two forms, dissociated ammonium ion (NH_4^+) and un-ionized ammonia (NH_3). The effect of pH and temperature upon the quantity of un-ionized ammonia present is important in determining the total concentration toxic to fish. As the pH increases, the quantity of un-ionized ammonia also increases. Increased temperature exacerbates the situation by also increasing the un-ionized portion.[4] The combined effect of these factors is illustrated in Table 3-3. This table specifies the concentration of ammonia required to obtain 0.025 mg/ℓ un-ionized ammonia, which has been considered a level at which no adverse effects occur. The typical lagoon operation may have pH levels between 9.0 and 10.0 units at temperatures between 20°C and 25°C. The amount of ammonia which is un-ionized at a pH of 9.0 and 20° is 28% and at a pH of 9.5 this increases to 56%. The typical amount of ammonia in lagoon effluents is between 5.0 mg/ℓ and 40.0 mg/ℓ ammonia. As the pH rises, the toxicity of the ammonia in the effluent increases.

Of the 164 lagoon operations covered under the IEPA proposed amendment, 82 of these are located in ammonia water quality limited areas. Ammonia removal is expensive, and complex, and small facilities, such as these lagoon operations, may be exempted from this requirement (as proposed in R77-6). High pH values typically occur in warm weather as a result of algal activity, and thus only need be controlled upon a

Table 3-3

EFFECTS OF TEMPERATURE AND pH ON UN-IONIZED AMMONIA CONCENTRATION

Temperature, °C	Concentrations of ammonia containing 0.025 mg/ℓ NH_3 un-ionized pH Value*					
	7.0	7.5	8.0	8.5	9.0**	9.5**
5	19.6	6.3	2.0	0.65	0.22	0.088
10	13.4	4.3	1.37	0.45	0.16	0.068
15	9.1	2.9	0.93	0.31	0.12	0.054
20	6.3	2.0	0.65	0.22	0.088	0.045
25	4.4	1.4	0.47	0.17	0.069	0.039
30	3.1	1.0	0.33	0.12	0.056	0.035

* 0.025 mg/ℓ NH_3 un-ionized considered a level at which no adverse effects occur.

**Criteria under these headings may be unduly low if there is little free carbon dioxide in the water.

Source: EIFAC, Report on Ammonia and Inland Fisheries

seasonal basis. Since many of these dischargers are on small streams, the effect of high pH and ammonia is an important consideration.

Adoption of the proposed pH regulation, without any exemption (Scenario C) would indeed enhance the water quality in those streams close to lagoon operations. However, if the IEPA proposed amendment (Scenario B) is adopted, then there will be a loss of protection for these small and intermittent streams. It is difficult to measure the benefits of increased protection for such streams but the effect of pH on ammonia toxicity should certainly be considered in the final evaluation of the proposed IEPA amendment.

To illustrate the projected impact of a lagoon discharger upon the water quality of a small stream, the following two hypothetical examples have been formulated.

Situation A

Parameter	Effluent Quality	Stream Quality	Mixing Zone Quality
Temperature	20°C	20°C	20°C
pH	9.5	7.5	8.7[1]
Flow	0.1 mgd	0.5 mgd	0.6 mgd
Ammonia	15 mg/ℓ	0 mg/ℓ	2.5 mg/ℓ
Unionized ammonia	8.3 mg/ℓ (maximum concentration)	0 mg/ℓ	0.42 mg/ℓ[2]

Situation B

Temperature	20°C	20°C	20°C
pH	9.5	7.5	8.9[1]
Flow	0.1 mgd	0.3 mgd	0.4 mgd
Ammonia	15 mg/ℓ	0 mg/ℓ	3.7 mg/ℓ
Unionized ammonia	8.3 mg/ℓ (maximum concentration)	0 mg/ℓ	1.0 mg/ℓ[2]

[1]This is a maximum pH expected and is calculated without allowing for buffering capacity of the stream.

[2]This is a maximum quantity of unionized ammonia to be expected in the stream.

These examples illustrate that the amount of un-ionized ammonia decreases as the effluent mixes with a small stream and the decrease is greater than that attributed to only dilution effects. Discharging a typical lagoon effluent quality can result in levels of un-ionized ammonia greater than 0.025 mg/ℓ immediately upon mixing. This concentration of 0.025 mg/ℓ un-ionized ammonia is one at which no adverse effects occur. Depending upon the stream size for mixing, the adverse of high pH and ammonia can range from chronic effects in fish to levels of acute toxicity. For 82 lagoon dischargers in ammonia water quality limited areas, the seasonal effects of high pH and ammonia are expected to be of an order of magnitude similar to the examples presented.

3.4 Nature and Value of Benefits

In Table 3-4 the assessment worksheet for benefit considerations summarizes the expected environmental consequences of adopting the proposed regulation and amendment. The most important benefit relates to the protection of aquatic life in small and intermittent streams located near municipal and private lagoon operations. The affect of pH on ammonia toxicity in wastewaters is a significant water quality problem. Little change is expected in other benefit categories because the measured impact of individual dischargers on general water quality is negligible.

Table 3-4

ASSESSMENT WORKSHEET
CROSS-CHECKLIST FOR BENEFIT CONSIDERATIONS
economic impact study

ALTERNATIVE ASSESSED pH effluent regulation

DESCRIPTION Adoption of a more stringent level of 6.0 to 9.0 units (Scenario C) with an exemption for biological processes (Scenario B)

REGULATION NO. R76-21 IEQ PROJECT NO. 80 '12 TITLE: Economic Impact of Change in pH Regulation

BENEFIT CATEGORIES	LEVEL OF INFORMATION							EXPLANATORY REMARKS
	QUALITATIVE BENEFIT ASSESSMENT	REFERENCE	QUANTITATIVE BENEFIT ASSESSMENT					
			Amount of Benefit	Units of Measure	Range of Benefit Uncertainty	$ Value	Range of $ Uncertainty	
1. Agriculture	Crop production is unaffected by irrigation with waters with a pH of 4.5 to 9.0 units. Water quality in such areas is unaffected by the regulation proposed.		Not measurable.	-	-	-	-	Streams with pH values outside the range of 4.5 to 9.0 units are not affected by the proposed regulation.
2. Commercial Fishing	The major rivers in which commercial fishing occurs are unaffected by the proposed regulation.		None	-	-	-	-	
3. Human Health and Public Water Supplies	Use of high or low pH waters is unpalatable and may cause increased corrosion of distribution pipes. Therefore, treatment of water supplies is required. Only one city, Carrier Mills, had a water source with an unsatisfactory pH; however, this city is unaffected by the proposed regulation.		Not measurable.	-	-	-	-	Water treatment costs may increase or decrease with the proposed regulation, depending upon the treatment techniques used and pH of the intake water. No significant changes are expected.
4. Industrial Water Supply	No measurable improvement in water quality for those streams used by industry is expected.		Not measurable.	-	-	-	-	
5. Recreation Water Contact	Although several streams in Illinois exceed the pH range of 6.5 to 8.3 designated as desirable to prevent eye irritation during swimming, no measurable change in water quality is expected as a result of the proposed regulation.		Not measurable	-	-	-	-	
6. Recreation - Fishing and Aquatic Life	Adoption of the regulation without the IEPA Amendment would enhance the water quality protection to small streams receiving lagoon effluents. Synergistic effects of pH and ammonia lead to toxic conditions in summer months for fish upon 164 sites of which 82 represent ammonia water quality limited areas.							Scenario C Scenario B

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Chapter 4

COSTS OF A pH REGULATORY CHANGE

4.1 Impacted Population

The total costs of more stringent pH control in effluents depend upon the type and number of dischargers affected. Upon review of Illinois Environmental Protection Agency (IEPA) analytical data, three impacted discharger groups have been identified. The following is a brief description of each group and their associated compliance problem:

a. Small municipalities (typically less than 2500 population equivalents), commercial establishments, and private facilities have treatment facilities consisting of lagoons or polishing lagoons. Due to the biological processes of algae, the pH limitation of 9.0 may be exceeded during warm weather.

b. Some industrial dischargers exceed the pH limitation of 9.0 because of high background levels in the water used. Presently exemption under 401 b of the Water Pollution Regulations covers these dischargers.

c. There are industrial dischargers who violate the proposed pH limitations because they have not installed pH pollution control equipment or because their treatment system presently achieves an effluent between 5.0 and 10.0 pH units.

Based upon the IEPA monitoring data, 331 municipalities, commercial facilities, and industries were identified with at least one violation of the proposed pH limitation. Since the present standard does allow values between 5.0 and 10.0 pH units, excursions of the 6.0 to 9.0 pH unit range at less than 10 percent frequency were assumed to be due to system error, and these dischargers were capable of attaining compliance without further costs. For those dischargers with pH violations occurring more than 10 percent of the time,

there may be an impact due to the proposed regulation. Even with this relaxed criterion, 244 dischargers were affected by the proposed regulation.

The categorization by discharger type and nature of the violation appears in Table 4-1. According to this table, 128 of the 244 dischargers are municipalities, and the proposed IEPA amendment would probably eliminate the regulatory impact upon 125 of these facilities. Lagoon operations comprise the greatest number of potential pH violators with 125 municipalities, 36 commercial and private facilities, and 3 industries. All of these dischargers would be exempted from pH control requirements, according to the IEPA proposed amendment. Other dischargers affected include six industries with high background water, five industries with insufficient treatment, and five with frequent failure of their treatment system. Nine facilities have installed or upgraded their pH treatment facilities to comply with pH limitations of 6.0 to 9.0 because of NPDES requirements (this group is not included since costs have already been incurred). Fifty-five other dischargers originally identified as violators have resolved their pH problems and no costs were assigned to these operations. The discharger segments identified in Table 4-1 represent the primary cost as the result of adopting the proposed regulation and considering the IEPA proposed amendment. Therefore, the costs presented in this chapter represent the expense of pH treatment by impacted discharges.

4.2 Costs of pH Control

The control of pH in effluents is a common and well proven treatment technology. Depending upon the discharger type and the nature of

Table 4-1

CATEGORIES OF pH VIOLATORS

Discharger Type	Number of Dischargers Violating for the Following Reasons: High Background Water[1]	Lagoons	Quality Control	Insufficient Treatment	Treatment System Installed[2]	Problem Corrected by Other Means	Problem Non-Existent[3]	Total
Commercial and Private								
Nursing Homes	0	3	0	0	0	0	1	4
Mobile Home Park	0	14	0	0	0	2	4	20
Schools	0	8	2	0	0	2	5	17
Miscellaneous	0	11	0	0	0	4	5	20
Manufacturing	6	3	2	4	6	7	19	47
Municipalities								
Sewage Treatment System	0	125	0	0	0	3	0	128
Water Treatment System	0	0	0	1	0	0	0	1
Utilities	0	0	1	0	3	0	3	7
Total	6	164	5	5	9	18	37	244

[1]High background water violators typically discharge water above the pH of 9.0. These dischargers were assumed to require treatment rather than be exempt under Rule 401b of Chapter 3, Water Pollution Regulations.

[2]These facilities were in violation according to IEPA 1975-1976 monitoring data, however, treatment has been installed since that time to comply with a pH of 6.0 to 9.0.

[3]These dischargers were in violation according to IEPA 1975-1976 monitoring data; however, NPDES data and recent conversations with IEPA personnel indicate these problems were corrected.

the pH excursion, separate treatment technologies with differing costs may be incurred. To obtain the costs of control, industrial dischargers were contacted for information and municipal costs were estimated on the basis of the technical literature. Before presenting the final costs, these technologies for controlling of pH are briefly described.

4.2.1 Control Technology

The control of pH depends, of course, upon the nature of the pH violation and the existing facilities for treatment. The definition of pH is important in understanding the significance of a change from 10.0 to 9.0 and from 5.0 to 6.0 pH units in the regulation.

pH is a measure of the acidic or basic activity of a solution on a scale from 0.0 to 14.0 standard pH units. A pH of 0.0 is highly acidic, 14.0 units is highly basic, and 7.0 is neutral. Acidic conditions are attributed to the presence of a greater number of hydrogen ions (H^+) than hydroxyl ions, and basic conditions are associated to a preponderance of hydroxyl ions (OH^-). When hydrogen ions and hydroxyl ions are present together in a solution, they neutralize one another and form water:

$$H^+ + OH^- \rightarrow H_2O$$

If unequal concentrations of hydrogen and hydroxyl ions are mixed, the solution will partially neutralize, and the resultant pH will remain on the side of the scale representing the greater concentration of the two.

It is important to note that a one unit change in pH represents a

ten-fold change in hydrogen ion concentration, and for this reason pH cannot be averaged to give a technically correct result.* Thus, a change in pH from 10.0 to 9.0 means that .0001 moles of hydroxyl ion must be reduced to .00001 moles (which requires additional chemical neutralization).

Several techniques of neutralization have been employed in treatment of acidic and basic wastes in a variety of industries. The selection of a process depends upon the cost of chemicals, neutralization rate and capacity, storage and equipment costs, ease of handling, and neutralization end products.[9] Table 4-2 contains a list of reagents commonly used in the treatment of acidic and basic wastes, and the specific selection is based upon the following criterion:[9]

> The choice of an acidic reagent for neutralization of alkaline wastewater is generally between sulfuric acid and hydrochloric acid. Sulfuric acid is usually selected because of its lower cost. Hydrochloric acid often has the advantage of soluble reaction end products, which may, however, cause the waste to contain high effluent dissolved solids.

Caustic agents commonly used to neutralized acidic wastes are sodium hydroxide, sodium carbonate, and various limes. Although sodium hydroxide is more expensive than other chemicals, its ease of storage and feeding, rapid reaction rate, and solubility of end products make it desirable in many situations.[9] The various forms of lime react more slowly and require larger mixing tanks and an involved reagent system, but their low cost and buffering effects make them a desirable reagent in many situations.[9]

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*see Appendix to Chapter 4.

Table 4-2

COMMON NEUTRALIZATION REAGENTS FOR ACIDIC AND BASIC EFFLUENTS

Reagent	Type	Effluent Treated
Sulfuric Acid	Acid	Basic
Hydrochloric Acid	Acid	Basic
Nitric Acid	Acid	Basic
Lump Limestone	Base	Acidic
Hydrated Lime	Base	Acidic
Sodium Bicarbonate	Base	Acidic
Sodium Hydroxide	Base	Acidic
Soda Ash	Base	Acidic
Carbon Dioxide	Base	Acidic

Source: Patterson, J., Wastewater Treatment Technology

Because pH is a logarithmic function, control processes must meet severe rangeability requirements. A two-unit change in pH represents a one-hundred fold change in ion activity, and the reagent addition system must have the capacity of a 100 to 1 change in addition rate. Thorough mixing is required to develop intimate contact between the reagent and the waste stream, and then the treated stream is held until the reaction can go to completion. Good measurement is critical to pH control, and any coating which accumulates on pH meter electrodes can make them sluggish in operation or inoperable.

The control technologies utilized in this study for achieving regulatory compliance are divided into the following three categories: specific design information from companies, a model treatment system for industries when data were not available, and a simple treatment

scheme for lagoon operations. For six companies specific pH treatment information, which is summarized in the appendix, was reported for completely new pH control systems. When data were not available, a model treatment system, shown in Figure 4-1 was used for cost information. This system, based upon Patterson's report, consisted of a continuous flow, one-stage reaction tank, chemical feeding equipment and automatic controls. Such a process represents a maximum cost incurred by those industrial dischargers required to install pH control equipment.

Municipal and commercial facilities presently operating lagoon treatment systems could utilize a simpler control scheme to resolve their pH problem. The high pH values observed in lagoon effluents are the result of algal photosynthesis in warm weather. During this process, carbon dioxide is extracted from carbonates and bicarbonates driving the equilibrium of equations 1 and 2 to the right, and producing hydroxyl ions.

$$2HCO_3^- \rightleftharpoons CO_3^{-2} + H_2O + CO_2 \qquad (1)$$

$$CO_3^{-2} + H_2O \rightleftharpoons 2OH^- + CO_2 \qquad (2)$$

This phenomenon only occurs during the warm weather months. Since lagoon operations typically have long (3 to 14 days) retention time, the simple addition of neutralizing chemicals, such as sulfuric acid, with some mixing capability would alleviate this problem. The only design alternative would be to add mixing and neutralizing facilities for pH adjustments after the lagoon. A range of costs is offered for lagoons which is representative of the latter type of treatment methods

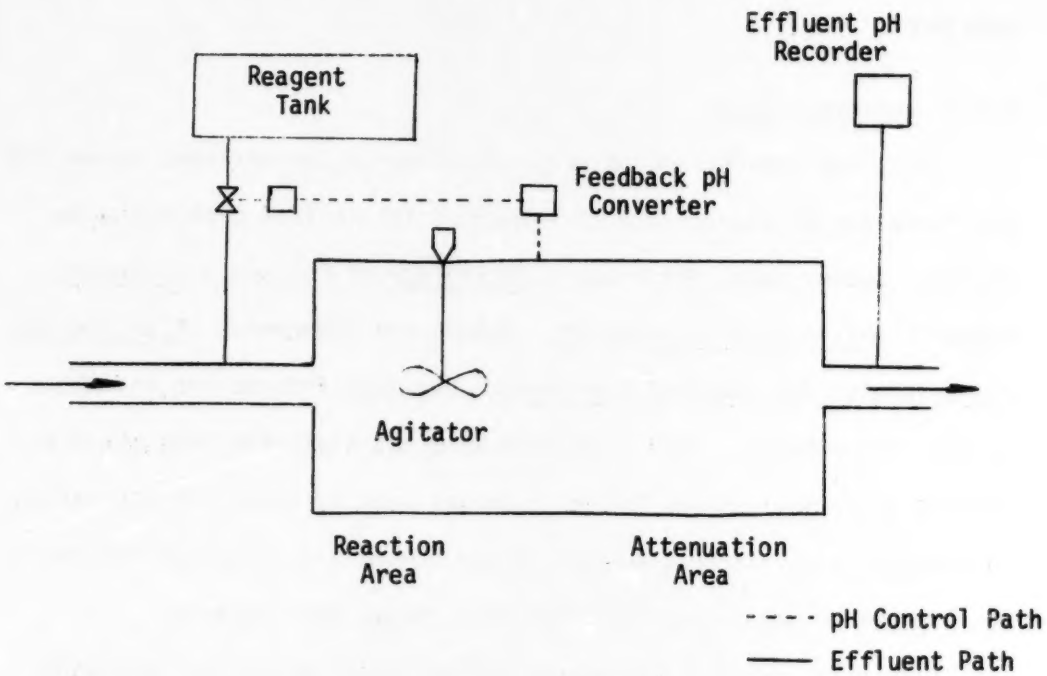

Figure 4-1

AUTOMATED pH CONTROL SYSTEM

available, and the costing methodology is detailed in the appendix.

Utilizing the company supplied information, the model system of Figure 4-1 for industries, and seasonal neutralization of lagoon operations, the total costs of treatment could be compiled. The following section presents unit treatment costs and total treatment costs associated with adoption of the proposed regulation and the proposed IEPA amendment.

4.2.2 Treatment Costs

Costs for controlling pH vary according to the effluent volume and the character of the wastewater. Sources for capital cost estimates include company data, Patterson's Technology of Pollution Abatement, Popper's Modern Cost Engineering, Peters and Timmerhaus' Plant Design and Economics for Chemical Engineers, and cost information obtained in U.S. EPA reports. When cost data were not available from the discharger, operating and capital cost curves were utilized for estimating treatment costs. In the appendix these curves are presented and the development of costs described for each discharger category.

Flow data for each discharger are based on one of the following four sources of information: NPDES permits, IEPA permits, direct communication with the discharger, and, in the case of municipalities, population based on the 1970 U.S. census. The data that are available through federal and state permits are not complete for all dischargers. Therefore, wherever the design flow of a discharger was not available, the estimate is based on the highest monthly flow reported since January of 1975, which is the earliest reporting point for NPDES. In

instances where the recorded discharge was not available, or where specific information concerning pH was desirable, dischargers were contacted and flow information was obtained directly. Where data on municipalities could not be obtained from permit information, flows were estimated based upon the population and an assumed flow of 375 liters per day per person.

Table 4-3 presents the capital costs for each discharger type if the proposed pH regulation is adopted. The total capital costs of adopting R76-21 would be between $3.8 and $5.6 million although $0.33 to $0.36 million has already been incurred by industry. If the IEPA exemption of lagoon dischargers is adopted, the anticipated capital costs drop to $0.7 to $0.9 million. These costs are divided among those with insufficient treatment, high background pH, and facilities already installed.

The increase in annual operating costs associated with the adoption of R76-21 would be less than $1 million in the entire state. Most of this operating cost is related to the annualized capital investment. If the lagoon dischargers are exempted, the annual operating costs would be $0.37 to $0.42 million for the 20 remaining dischargers.

The costs of Tables 4-3 and 4-4 represent the entire expected costs of the adoption of regulatory proposal R76-21. In Chapter 5 these values are discussed as a balancing factor to the anticipated benefits of regulation.

Table 4-3

pH CONTROL SYSTEMS--CAPITAL COSTS ESTIMATES*

Type of pH Violation	Discharger Category	Low Cost Estimate, $		High Cost Estimate, $	
Lagoons	Municipalities	2,780,000		4,010,000	
	Industries	40,000		80,000	
	Utilities	0		0	
	Commercial/Private				
	Schools	70,000		190,000	
	Trailer Parks	120,000		340,000	
	Nursing Homes	4,000		20,000	
	Miscellaneous	90,000		270,000	
Subtotal			3,104,000		4,910,000
Insufficient Treatment	Municipalities	40,000		0	
	Industries	150,000		300,000	
	Utilities	20,000		20,000	
	Commercial/Private	0		0	
Subtotal			210,000		510,000
High Background pH	Municipalities	0		0	
	Industries	160,000		170,000	
	Utilities	0		0	
	Commercial/Private	0		0	
Subtotal			160,000		170,000
pH Treatment Installed	Municipalities	0		0	
	Industries	260,000		260,000	
	Utilities	70,000		100,000	
	Commercial/Private	0		0	
Subtotal			330,000		360,000
Total for all categories			3,800,000		5,950,000

*Cost methodology is shown in Appendix B of Chapter 4.

Table 4-4

pH CONTROL SYSTEMS--CHEMICAL AND OPERATING COSTS

Type of pH Violation	Discharger Category	Chemical Cost, $x10^3$	Depreciation Cost, $ Low Estimate, $x10^3$	Depreciation Cost, $ High Estimate, $x10^3$	Operating Cost, $x10^3$
Lagoons	Municipalities	31.3	241.9	348.9	
	Industries	0.5	3.5	7.0	
	Utilities	0	0	0	
	Commercial/Private				
	Schools	0.1	6.1	16.5	
	Trailer Parks	0.2	10.4	29.6	
	Nursing Homes	0	0.3	6.1	
	Miscellaneous	0.2	7.8	23.5	
Subtotal		32.3	270.0	431.6	302.3-463.9
Insufficient Treatment	Municipalities	12.4	5.2	24.9	
	Utilities	1.4	2.6	2.6	
	Industries	165.8	19.6	39.3	
	Commercial/Private	0	0	0	
Subtotal		179.6	27.4	66.8	207.0-246.4
High Background pH	Municipalities	0	0	0	
	Utilities	0	0	0	
	Industries	22.7	21.0	22.3	
	Commercial/Private	0	0	0	
Subtotal		22.7	21.0	22.3	43.7-45.0
Treatment Installed	Municipalities	0	0	0	
	Industries	58.3	34.1	34.1	
	Utilities	19.9	9.2	13.1	
	Commercial/Private	0	0	0	
Subtotal		78.2	43.3	47.2	121.5-125.4
Total		312.8	361.7	567.9	674.5-880.7

*Operating cost is defined as the sum of the chemical and depreciation costs of columns 3, 4, and 5.

Chapter 5

COMPARISON OF BENEFITS AND COSTS

The expected total costs and benefits of adopting the proposed pH regulation R76-21 have been described in Chapters 3 and 4. A simultaneous comparison and discussion of such values indicate those water users who will benefit from the regulation modification and those who must pay the costs. Section 1 presents this discussion as well as the economic reallocation resulting from this adoption. Section 2 presents a sensitivity analysis of these results and examines the factors which influence the magnitude of both costs and benefits.

5.1 Benefits and Costs of Regulation

There is a reallocation of economic resources as a result of adopting the proposed regulation since costs are incurred by several discharger groups and benefits accrue to others. To summarize these expected benefits in conjunction with the costs incurred, Table 5-1 is presented. According to Table 5-1, the difference in benefits between Scenarios B and Scenario C is the level of protection afforded small and intermittent streams upon which 164 lagoon dischargers are located. Other water users will realize insignificant benefits from adoption of Scenario B or Scenario C.

The annual costs associated with Scenario B and Scenario C have been quantified for those dischargers impacted by the regulation. Inclusion of the IEPA amendment provides relief for 164 small municipalities and private dischargers, which represents over 83% of the annual costs

of Table 5-1. The required capital investment associated with the proposed regulation (Scenario C) is between $3.3 million and $5.3 million, and with the IEPA amendment (Scenario B) this drops to $0.37 million to $0.07 million. Adopting the IEPA amendment reduces the number of dischargers incurring costs from 189 to 25. Thus, the costs of Scenario C are primarily incurred by municipalities and a small number of industrial dischargers and those of Scenario B incurred by just the small number of industrial dischargers.

Table 5-1

SUMMARY OF BENEFITS AND COSTS OF REGULATION

Regulatory Scenario	Total Annual Costs* $x10^6$	Total Benefits
A (Existing)	0	Base level
B (Proposed R76-21 and IEPA Amendment)	0.25-0.29	Negligible benefits to water users
C (R76-21)	0.55-0.76	Negligible benefits to water users plus improved protection for biota in small and intermittent streams upon which 162 lagoon dischargers are located.

*Total annual costs represent a combination of chemical costs and annualized capital cost only.

5.2 Sensitivity Analysis

There are two important assumptions utilized in estimating the costs and benefits of R76-21 and the IEPA amendment, and these assumptions affect the conclusions. Each is discussed in the following paragraphs as to its importance and impact upon the results obtained:

5.2.1 Measurement of changes in water quality

In estimating environmental consequences and user benefits, no significant change in water quality was expected to be measured, based on IEPA monitoring stations. The 164 lagoon dischargers may increase the stream pH temporarily during warm weather such that some other stream uses such as swimming or irrigation could be affected. This would raise the environmental benefits from a level not measurable to a larger quantity. Quantification of such benefits is, however, still so small as to be not measurable.

5.2.2 Alternate treatment methods for lagoons

It is possible that to obtain satisfactory pH control in lagoons treatment methods other than additional pH control equipment may suffice. If methods for reducing algae were employed or if manual chemical addition were used, the costs of treatment would be higher or lower, respectively. The range of costs presented in the study represent average values expected for a pH system. If additional aeration and filtration were used to eliminate algae, the costs would be orders of magnitude higher; however, improved water quality and therefore additional benefits would be realized. Simple manual addition of chemicals would eliminate most capital investment and result in primarily chemical and labor expenses.

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APPENDIX TO CHAPTER 4

APPENDIX A TO CHAPTER 4

Averaging of pH

The technical definition of pH is the negative logarithm of the hydrogen ion concentration. If the hydrogen ion concentration is 10^{-3} molar, or 0.001 molar, the pH is three. A simple average of pH three and pH seven gives an answer of five: $\frac{3 + 7}{2} = 5$. An average of the actual concentrations gives an answer that corresponds to a pH of 3.3:

$$\frac{0.001 + 0.0000001}{2} = 0.00050005$$

$$0.00050005 = 10^{-3.3}$$

$10^{-3.3}$ corresponds to pH 3.3.

APPENDIX B TO CHAPTER 4

Industrial Capital Costs

Costs of pH treatment for industrial process waters are based on a model treatment system from Patterson's Economics and Technology of Industrial Pollution Abatement (originally published in "Plating," 55:1171-1179, 1968) or from data obtained from companies. In Table A-1 the available cost information is presented. These costs have been updated to 1977 dollars using the Marshall and Stevens index[3] factor of 1.83. Figure A-1 and Figure A-2 are the curves used to determine capital costs and operating costs, respectively, based upon the model of a continuous flow, single stage reaction tank with fully automatic controls. pH treatment systems with less than fully automatic controls are available at lower costs, but a fully automatic system is used here to determine the maximum costs that would be incurred upon enactment of the new pH limits.

The model presented by Patterson was limited to a flow range of 150 liters per minute to 760 liters per minute. Because several dischargers reported flows outside this range, extrapolation of the curve was necessary. Where discharges were less than 150 liters per minute, a linear extrapolation of the curve served to fix a low-cost estimate, as shown in Figure A-1, while the low point of the original curve fixed a high-cost estimate. Where discharges were reported as greater than 760 liters per minute, costs were extrapolated by multiplying the highest cost reported on the curve ($40,100) by a factor of the quantity of reported flow divided by 760 liters per minute raised to the 0.6 power

$$\text{high cost} = \$40{,}100 \left(\frac{\text{reported flow}}{760\ \ell\text{pm}}\right)^{.6}$$

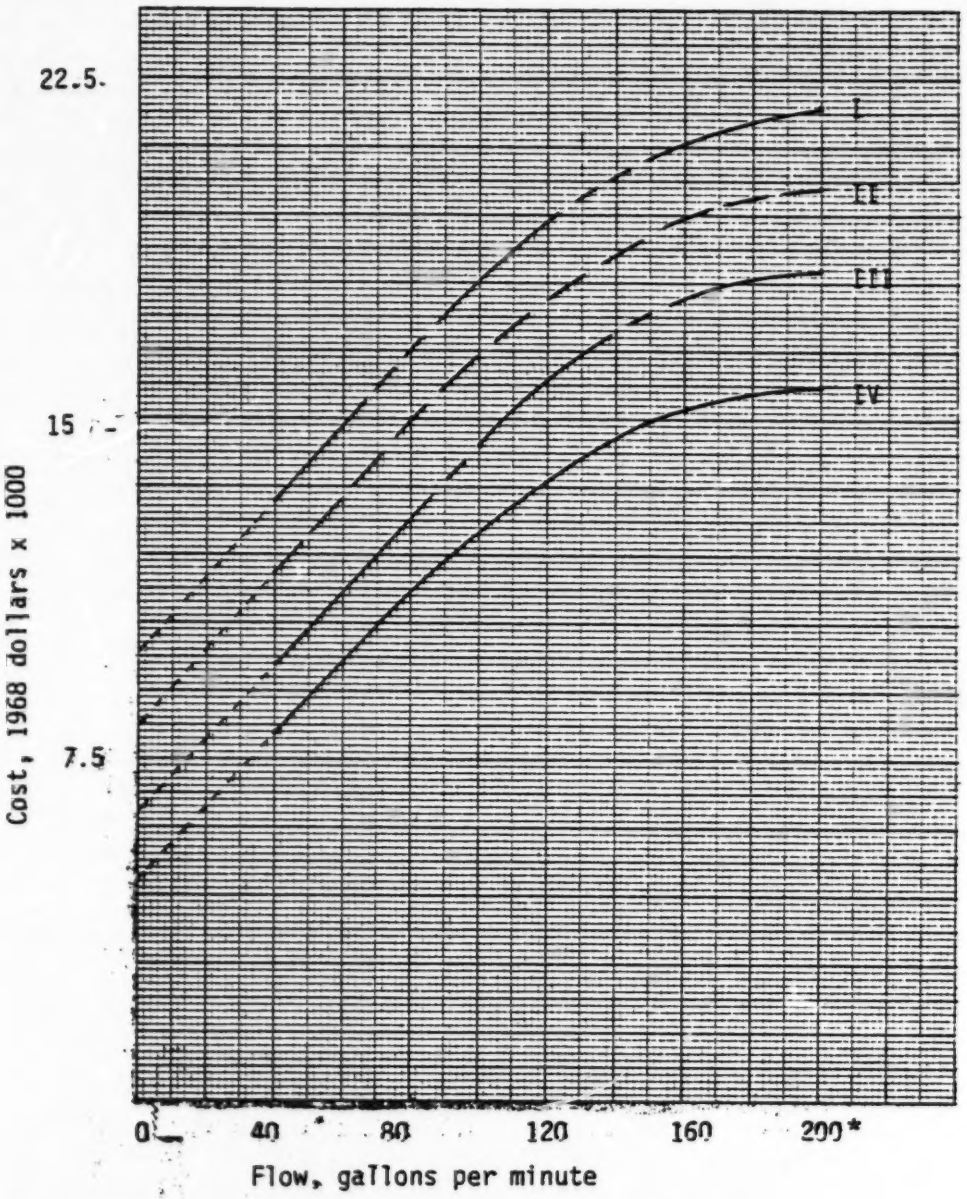
The low cost was reported as the highest point on the original curve,

Table A-1

COSTS OF pH CONTROL SYSTEMS REPORTED BY DISCHARGERS

Discharger	Location	pH Treatment System	Flow (liters/day x 10^6)	Capital Cost (Dollars)	Annual Operating Cost (Dollars)
AMF Wheelgoods	Olney	Caustic soda addition	0.327	20,000	12,000
Olin Brass	East Alton	Chlorination	23.656	105,000	24,000
		Sulfuric acid addition	1.892	41,000	13,000
Central Illinois Public Service	Grand Tower	Carbon dioxide injection (leased)	15.518	16,700	11,000
Alumax	St. Charles	Mix acidic and basic waste streams	0.121	12,000	0
Firestone Tire & Rubber*	Bloomington	Sulfuric acid addition	0.057	26,500	4,500

*System not yet installed.

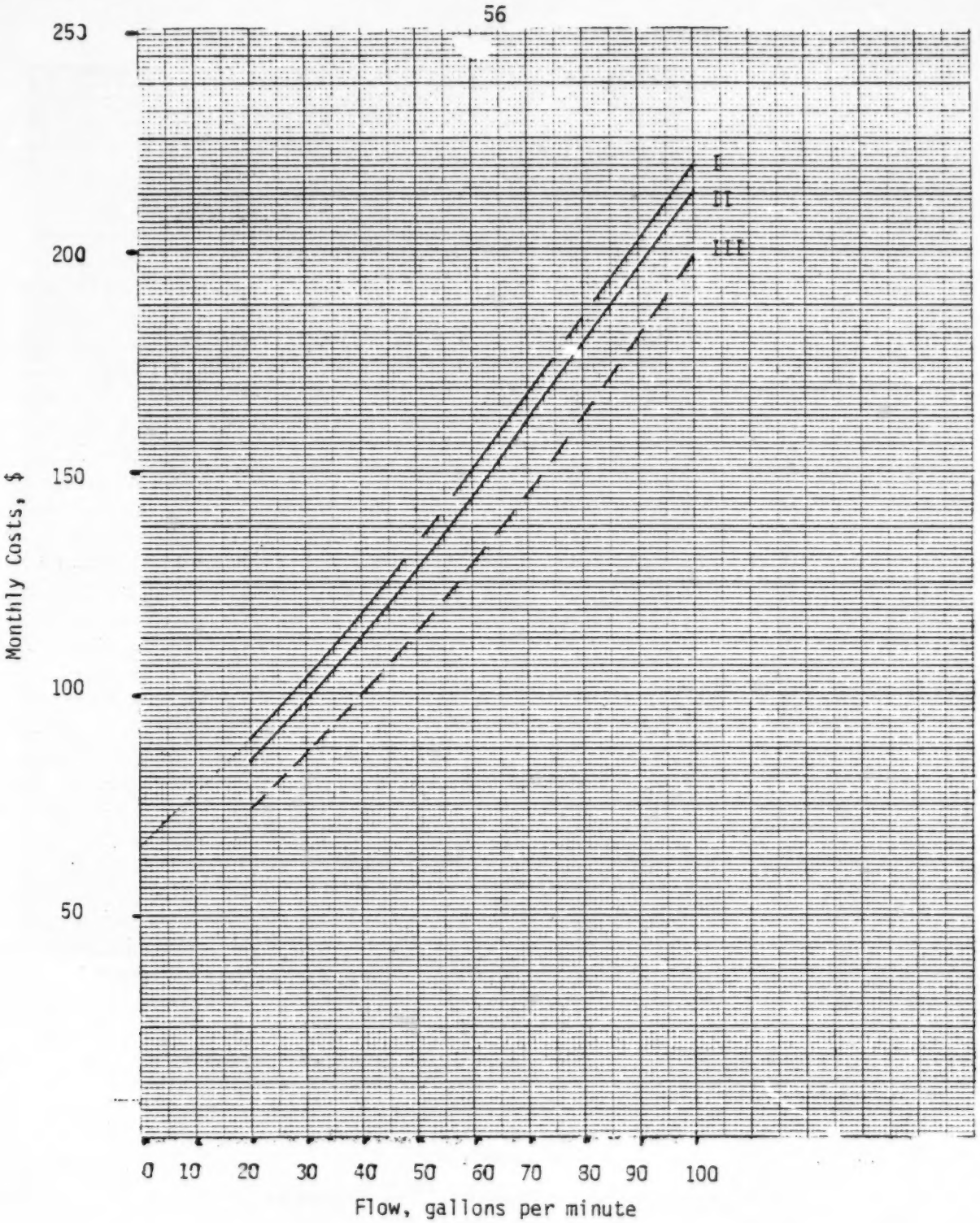


I Full Instrumentation
II Medium Instrumentation
III Manual Controls
IV Package Plant

Figure A-1

CAPITAL COSTS FOR INDUSTRIAL pH TREATMENT

*Comparable to 760 liters per minute.



I Full Instrumentation
II Medium Instrumentation
III No Instrumentation

Figure A-2

CHEMICAL COSTS

$40,100.

Costs of flows within the range 150 to 760 liters per minute were read directly from the curve.

Lagoon System and Polishing Pond Capital Costs

Lagoons and polishing ponds could utilize a pH treatment system that is simpler than that used for industrial waste streams. Detention times in lagoons are typically 3 to 14 days, and there is no need to monitor the effluent for shock loads of highly acidic or basic chemicals. Also, this equipment would only be used from three to six months of the year.

For these reasons, capital costs for pH treatment in lagoon systems and polishing ponds have been estimated with a model treatment system consisting of a single-cell mixing tank, agitator, and a chemical control loop from a 55-gallon shipment drum. Cost figures for this system are based on Popper's Modern Cost Engineering Techniques and Peters and Timmerhaus' Plant Design and Economics for Chemical Engineers, and are listed in Table A-2. Figure A-3 is the graph of cost vs. flow as generated by the model. Prices were updated to 1977 dollars by the Marshall and Stevens index.

To insure that a representative range of costs were included in the cost estimate of lagoon operations, maximum costs were calculated from the automated industrial treatment system discussed previously.

Chemical Costs

Chemical costs are based on the prices of sulfuric acid and sodium

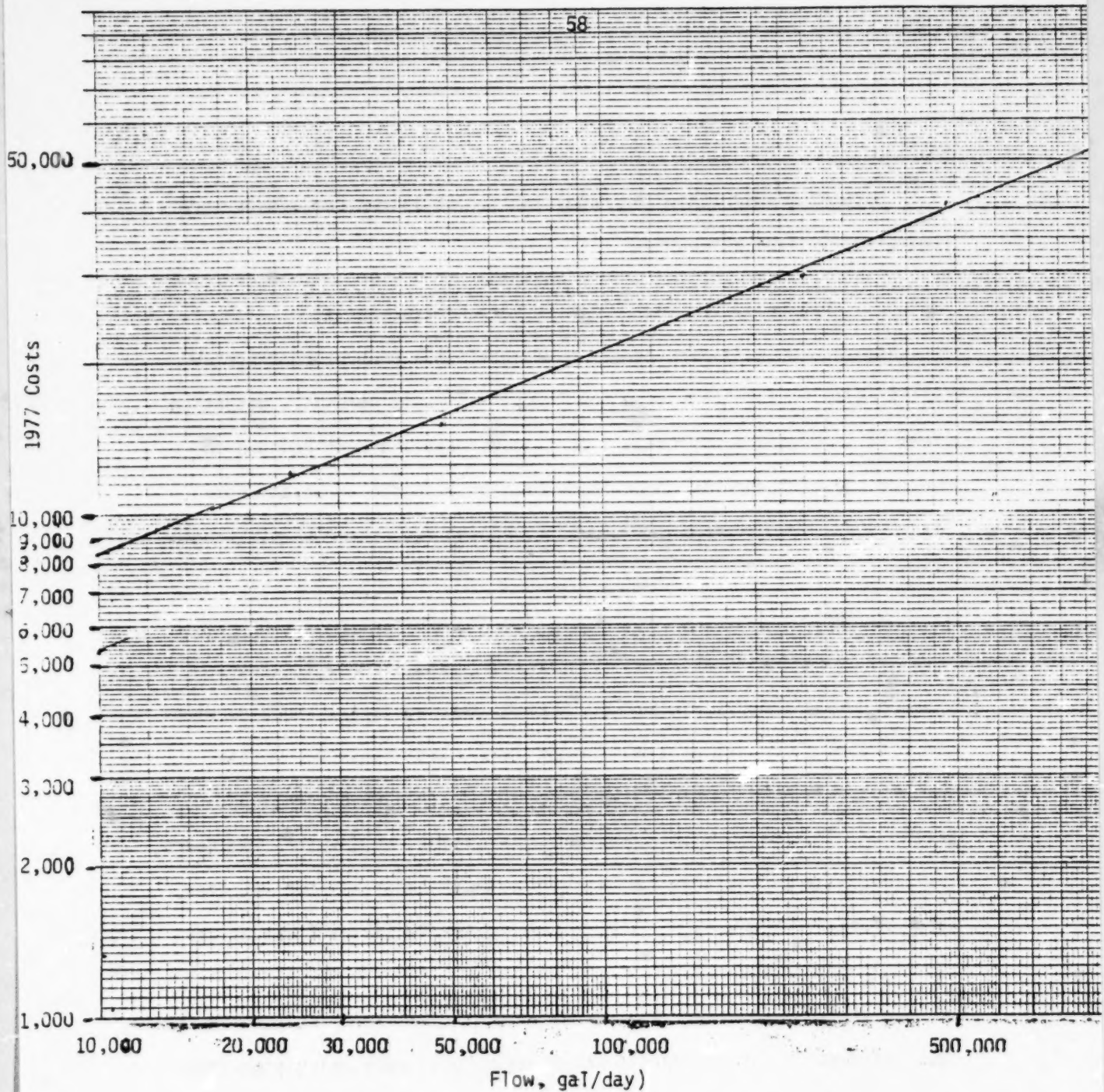


Figure A-3

1977 COSTS FOR LAGOON TREATMENT SYSTEM CONSISTING OF MIXING TANK IN AGITATOR AND pH CONTROL LOOP FROM 55 GAL DRUM OF ACID

Table A-2

COSTS FOR LAGOON TREATMENT SYSTEM[1]

Volume of Treatment System, gpd	Total 1977 Equipment Costs	Total 1977 Installed Cost[2]
4,800	$ 1,000	$ 6,800
24,000	2,400	12,000
48,000	3,200	15,100
240,000	7,000	29,300
480,000	10,000	40,700

[1]Costs do not include engineering fee contingency cost, and supporting facility modification.

[2]Installed cost factor is 1.96, Marshall & Steven index factor is 1.92, and control cost of $3000.
Total installed cost = 1.96 x 1.92 x equipment cost + control cost.

hydroxide, two chemicals that are commonly used to treat basic and acidic wastes respectively. Because the quantities of chemicals needed to treat most of the discharges listed here are small, the prices used are based on the purchase of small quantities.

The specific assumptions and calculations that were used to estimate annual chemical costs are as follows:

A. Assume neutralization of basic wastes from pH 10 to pH 7. Assume neutralization of acidic wastes from pH 4 to pH 7. When pH = 10, the concentration of hydroxide ions, $[OH^-]$, is 10^{-4} moles/liter. When pH = 4, the concentration of hydrogen ions, $[H^+]$, is 10^{-4} moles/liter. Neutralization of 10^{-4} moles/liter of OH^- or H^+ requires 10^{-4} moles of H^+ or OH^- respectively.

B. Assume sulfuric acid (molecular weight H_2SO_4 = 98 g/mole) used to neutralize bases and sodium hydroxide (molecular weight NaOH = 40 g/mole) used to neutralize acids.

Because 1 mole H_2SO_4 yields 2 moles of H^+, ($H_2SO_4 \rightleftarrows 2H^+ + SO_4^=$), need 0.5×10^{-4} moles H_2SO_4 per liter basic effluent, or $0.5 \times 10^{-4} \times 98$ g/ℓ = 0.0049 g H_2SO_4/ℓ.

Because 1 mole NaOH yields 1 mole of OH^-, ($NaOH \rightleftarrows Na^+ + OH^-$), need 1.0×10^{-4} moles NaOH per liter acidic effluent, or $1.0 \times 10^{-4} \times 40$ g/ℓ = 0.004 g NaOH per liter.

C. Assume buffering capacity of waste streams doubles the demand for chemicals.

2×0.0049 g H_2SO_4/ℓ = 0.0098 g H_2SO_4/ℓ

2×0.004 g NaOH/ℓ = 0.008 g NaOH/ℓ

D. Assume prices of chemicals to be:

H_2SO_4 = \$2.3 x 10^{-4} per gram

NaOH = \$5.5 x 10^{-4} per gram.

The price of H_2SO_4 is based on the purchase of 15 gallon containers (215 pounds per container) of 93% H_2SO_4 listed at \$9.75 per 100 pounds (total weight) FOB Chicago, October, 1977. This corresponds to a price of \$10.48 per 100 pounds of 100% H_2SO_4. The price of NaOH is based on the purchase of 100 pound drums at \$0.25 per pound, as quoted in "Chemical Marketing Reporter."

E. Assume lagoon operations require treatment 182.5 days per year, all other systems require treatment 365 days per year.

F. Calculations are as follows:

Cost of H_2SO_4 per year = 0.0098 g H_2SO_4/liter effluent x \$2.3 x 10^{-4}/g H SO x liters of effluent/day x number of days required/year

Cost of NaOH per year = 0.008 g NaOH/liter effluent x \$5.5 x 10^{-4}/g NaOH x liters of effluent/day x number of days required/year

G. Several dischargers impacted by the proposed change did not report flow measurements. Flow assumptions made for those discharges are as follows:

1. Municipalities: flow = 379 liters per person per day. Where population figures were not available, population was assumed to be 100 persons.
2. Nursing homes: flow = 3,790 liters per day.
3. Schools, mobile home parks, and miscellaneous private/commercial businesses: flow = 37,900 liters per day.

H. IEPA data served to identify 244 dischargers which have had pH violations in 10% or more of the grab samples analyzed by the IEPA in 1975 and 1976. Other sources of information were consulted to establish whether a pH problem existed for each discharger. If these other sources did not supply information that would establish the presence or absence of a pH problem, the assumption was made that a problem exists, based on the violations recorded in the IEPA data list. This assumption was made for 14 dischargers.

I. No costs are assigned to dischargers which have exceeded the pH limit 6.0 to 9.0 due to quality control difficulties. It is assumed that these excursions can be eliminated through increased maintenance of existing facilities, and therefore capital expenditures are not required.